Options, Benefits, and Liabilities for Copper Sprays in Tree Fruits

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Copper fungicide/bactericide sprays have proven useful for managing fire blight of apples and pears, peach leaf curl and bacterial spot on peaches and nectarines, and bacterial canker on cherries and apricots. Many different copper products are registered for these uses, and it is difficult to know which product to select for any given application. In this article we will explain some of the differences among copper formulations and some things to consider when choosing a copper fungicide/bactericide for controlling tree fruit diseases. Reviewing the literature for this article caused me to revise some of my own long-held perceptions about factors that impact the efficacy of copper sprays.

Copper sprays control plant pathogens because copper ions denature proteins, thereby destroying enzymes that are critical for cell functioning. However, copper ions are non-selective. If copper ions enter plant tissues they can kill plant cells as well as cells of fungal and bacterial pathogens. The outer protective layers on plants (i.e., bark woody tissues, cuticle and epidermal cells on leaves and fruit) prevent copper from penetrating and killing host tissue whereas bacterial cells and fungal spores landing on trees are more directly exposed to the copper ions on the surface of plants that have been treated with copper. Copper can kill pathogen cells on plant surfaces, but once a pathogen enters host tissue it will no longer be susceptible to copper treatments. Thus, copper sprays act as protectant fungicide-bactericide treatments, but copper sprays lack post-infection activity.

Because copper ions are broadly toxic to living cells, copper treatments applied to plants must be adjusted so that enough copper ions are present to kill the target pathogens while still keeping the concentration of copper ions low enough to avoid injury to the plants that are treated. One way of limiting the copper ion concentration on plant surfaces is through the use of copper products that are relatively insoluble in water.

The oldest copper product used in agriculture is copper sulfate, which was used in the early 1800's as a seed treatment for wheat. Copper sulfate, also known as copper sulfate pentahydrate, has a solubility in water of 320 mg/L at 68 °F. Because of its high solubility in water, copper sulfate can cause phytotoxicity even at relatively low application rates because a large quantity of copper ions will be present on treated plant surfaces anytime water is present. The high solubility also means that copper sulfate residues can be rapidly removed by rainfall.

Figure 1. A typically pale-blue formulation of basic copper sulfate (top) contrasts with the red color of copper oxide (Nordox, bottom). Both products are effective for applications on tree fruits.

Copper products registered for tree fruits are almost all "fixed coppers" that have low solubility in water. In fact, many of the fixed copper compounds are considered totally insoluble in water in their purest forms. However, tests of formulated copper products usually show water solubility in the range of 2 to 6 mg of copper per liter. When these fixed copper products are mixed with water in a sprayer, the spray solution is actually a suspension of copper particles, and those particles persist on plant surfaces after the spray dries. Copper ions are gradually released from these copper deposits each time the plant surface becomes wet. The gradual release of copper ions from the copper deposits provides residual protection against plant pathogens. At the same time, the slow release of copper ions from these relatively insoluble copper deposits reduces risks of phytotoxicity to plant tissues.

Fixed coppers include basic copper sulfate (e.g., Cuprofix Ultra Disperss), copper oxide (e.g., Nordox), copper hydroxide (e.g., Kocide, Champ), copper oxychloride sulfate (e.g., COCS), and copper ions linked to fatty acids or other organic molecules (e.g., TennCop, Cueva). Note that basic copper sulfate behaves differently than copper sulfate because the addition of hydroxyl ions (i.e., OH ions) changes copper sulfate into a relatively non-soluble fixed copper. With traditional Bordeaux mix, which is a mixture of copper sulfate plus lime, the chemical change occurs in the spray tank as the hydroxyl ions from the lime complex with the copper sulfate to form a fixed copper. Note also that not all copper compounds are blue. Nordox, a copper oxide product, is a rusty red color (Fig. 1).

Efficacy of copper sprays is dependent on the amount of elemental copper (sometimes listed on the label as percent metallic copper) that is applied and on how finely the copper ingredient has been ground. Very little work has been done to compare effectiveness of different copper formulations applied to apples, pears, and stone fruits at the delayed dormant or green tip bud stages. Therefore, we are forced to derive our conclusions about copper efficacy from studies on other crops such as citrus, tomatoes, olives, and walnuts. For many years, the preponderance of evidence indicated that efficacy of copper applications was directly related to the amount of elemental copper actually applied. This simplified purchasing decisions because one could conclude that a copper product containing 50% elemental copper would be directly comparable to another product containing 25% elemental copper so long as the latter was applied at double the rate of the former.

However, other research has shown that finely ground copper formulations are more active than coarsely ground formulations. Hardy et al. (2007) listed some of the copper products available in Australia and reported that their median particle sizes ranged from 0.7 microns to 3.1 microns. Many of the products listed are not available (at least under those trade names) in the United States, but the copper products that we use probably have a similar range of particle sizes. Note that the median particle size cannot be determined just by looking at the formulated products because the granule size of the final formulation is not directly related to how finely the copper was ground prior to being formulated.

The difference between 0.7 and 3.1 microns may sound rather insignificant, but the potential impact of particle size becomes more obvious if one calculates how particle diameter relates to particle volume. A sphere with a diameter of 2.8 microns will contain 64 times more volume than sphere with a diameter of 0.7 microns. Therefore, copper products with a median 0.7-micron particle size would theoretically have 64 times more copper particles distributed across and adhering to treated plant surfaces than would occur following application of a copper product with a 2.8-micron particle size if rates of both products were adjusted so as to generate the same rate of metallic copper per acre. (I realize that copper particles in aqueous solutions may not be true spheres, but the general principle still applies.) Thus, one should be able to achieve more complete coverage with a finely ground copper compared to a coarsely ground copper. Furthermore, research as shown that the larger copper particles are more subject to removal by wind or rainfall acting on the leaf surfaces after sprays have dried. Therefore, finely ground copper products have better residual activity.

Not surprisingly, finely ground copper formulations are usually more expensive and are labeled for use at lower rates. Unfortunately, I am not aware of any good studies that explain how to adjust rates of elemental copper to compensate for the increased efficacy of finely-ground compared to more coarsely ground copper products. Without that data it is difficult to know whether it is better to pay less for a coarsely ground copper that will end up supplying a higher rate of elemental copper/A (i.e., the traditional way of thinking) or whether to pay more per pound of elemental copper for a finely ground formulation that may have better residual activity even when it is applied at lower rates of elemental copper per acre.

The finely ground coppers may be preferable for delayed dormant and dormant applications for several reasons. We have already noted that, at any given rate of elemental copper, finely ground products will provide more copper particles per acre and the finely ground copper formulations will be less subject to removal by wind and rain. The objective of delayed-dormant and green-tip applications on tree fruits is to generate a copper residue in the tree that will persist and provide disease control that extends through leaf development stages where further applications of copper would cause excessive phytotoxicity. Thus, having a copper formulation that provides extended residual activity should be an advantage so long as the rate is properly adjusted so as to avoid the phytotoxicity that can result if excessive copper residues persist when trees come into bloom. Using lower rates of finely ground copper will also help to avoid toxic accumulations of copper in soils. Copper in soils can suppress earthworm populations and may also adversely affect other soil microorganisms.

Because we lack experimental evidence concerning rate adjustments for finely ground coppers, we suggest that growers proceed with caution when switching from older coarsely ground copper formulations to newer finely ground formulations. Rates should be adjusted to stay within the rates indicated on product labels, but most copper labels list a broad range of rates. In general, the upper end of labeled rates are suggested for applications that are made at silver tip or green tip, especially when those bud stages occur early and one can therefore expect a long, drawn-out timeframe for bud development. The lower ends of labeled rates are suggested for applications at green tip (or even at half-inch green, in an emergency), especially if one expects trees to advance rapidly from bud break to bloom. Using excessive rates of copper, especially finely ground coppers that have good residual properties, could result in fruit russetting on some apple cultivars if copper ions are splash-dispersed to developing fruit tissue after flowers reach pink or bloom.

Copper products such as TennCop (which is no longer being produced) and Cueva contain very low concentrations of elemental copper because the copper is linked to other organic compounds. Although we have not tried using these compounds in green-tip sprays, we doubt that the low amounts of elemental copper provided by the labeled rates will provide sufficient residual activity for controlling the pathogens targeted by these early copper applications. These products are better suited for applications later in summer when low rates of copper are desired so as to minimize phytotoxicity. In fact, TennCop was used for many years by peach growers who applied it in a carefully specified regimen to control bacterial spot.

Following are a few additional concepts relevant to using copper products on tree fruits:

1. Solubility of fixed coppers increases under acidic conditions. As a result, copper sprays will become more phytotoxic if they are applied in an acidic solution. Acidifiers such as LI-700 and non-buffered phosphite fungicides should not be tank-mixed with copper fungicides.

2. Copper sprays generally cause more phytotoxicity to the sprayed foliage when applied under slow-drying conditions as compared to rapid-drying conditions. This concern is not relevant for delayed dormant or green-

tip applications. However, if copper is used to control bacterial spot during summer or if it is applied to non-bearing apple trees to control fire blight after leaves have emerged, then phytotoxicity can be minimized by applying the copper with relatively low volumes of water and under conditions where droplets dry quickly.

3. When buds are already showing green tissue, do not apply copper just prior to predicted frosts because the cells ruptured by frost crystals may resorb and be killed by the copper on the bud surfaces.

4. The literature on the benefits of using adjuvants with copper suggests that adjuvants have highly variable and largely unpredictable effects on the efficacy of copper sprays. We know from years of experience that copper products can be combined with oil in delayed dormant or green-tip sprays if oil is being applied to control mites. Otherwise, using one quart of spray oil per 100 gallons of finished spray solution may enhance coverage of the wood in these early-season sprays, but using higher rates of oil does not "lock in" the copper deposits to enhance residual activity. No other adjuvants are necessary or recommended on tree fruits.

5. As noted earlier, Bordeaux mixture was made by mixing copper sulfate and spray lime. With the fixed copper products, there is no published evidence that adding spray lime will either reduce phytotoxicity or extend the residual activity of the copper. However, at a recent meeting, several sweet cherry growers in the Cumberland-Shenandoah region told me that they achieved much better control of bacterial canker when they added spray lime to copper sprays even though they were using a fixed copper that theoretically did not need any additional lime. At this point, I have no hypothesis to explain their observations.

Literature Cited

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